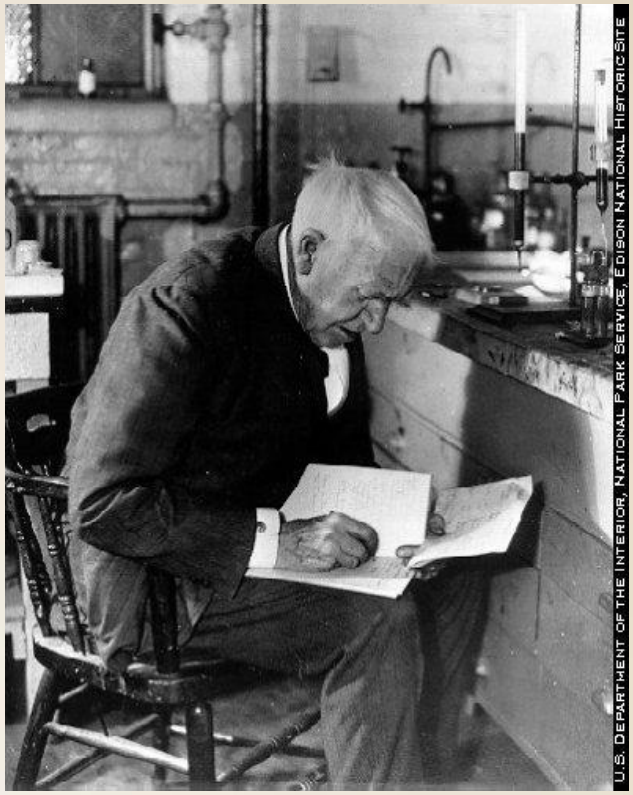


Laboratory notebooks

Colorado State University

Fernando Tomasel
Adjunct Faculty, ECE Department
VP of Engineering, Petra Systems

Starting with a broader picture

- Maintaining good notebooks is essential for all sorts of activities, ranging from scientific research to the arts.

- Writing notebooks is part of a much broader endeavor: the creation, documentation and dissemination of knowledge.

- There are many resources available regarding scientific writing, including lab notebooks. The book "*The art of scientific writing: from student reports to professional publications in chemistry and related fields*", by H.F. Ebel, C. Bliefert, and W.E. Russey (Wiley, 2004, available from Google books) is a good example.

The need for documentation

- Virtually all employers in the fields of science and engineering require employees to document their activities through the generation of internal reports, patents, presentations, papers in trade magazines and scientific journals, etc.

- Laboratory notebooks are the basic source of information for most of these forms of communication and dissemination.

- We will use the words “lab notebook” to describe all sorts of basic research records (no matter if you work in a lab, or run simulations, or write code, or whatever)

The need for documentation

- Employers require good documentation for a number of reasons, including securing intellectual property, keeping projects on track, reducing training and knowledge transfer time, complying with regulations, etc.

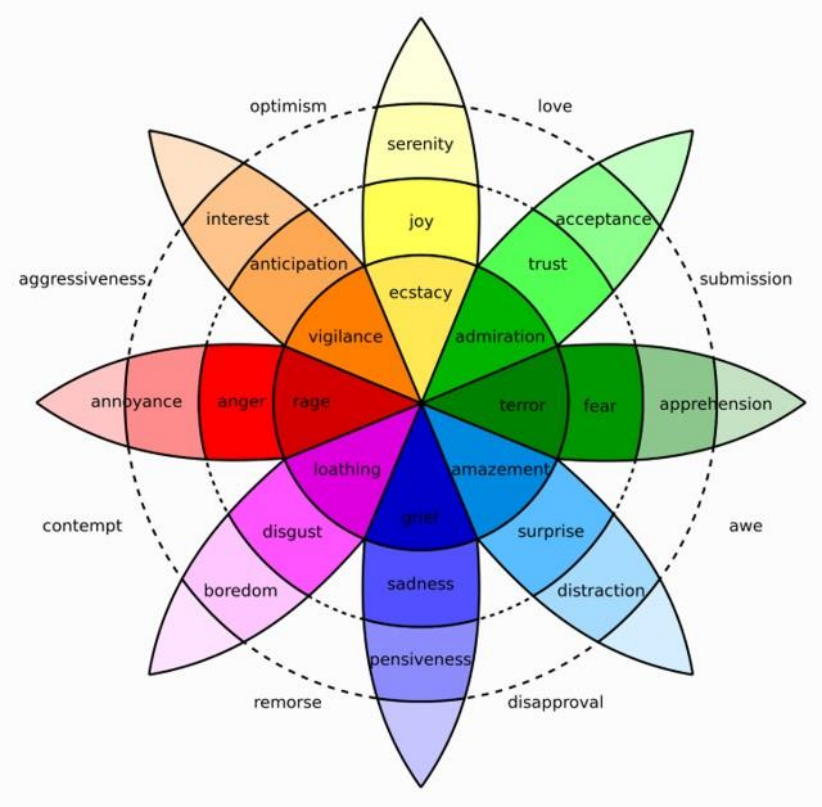
- But you should see that there good reasons for you to do it anyways: among many other benefits it will minimize time wasted, and it will show that you are a professional - someone who cares enough to write down and analyze what he/she does.

The need for documentation

- Many people from the younger generations like to document every instant of their day using tools such as Facebook, Twitter, Instagram, Snapchat, etc.

- If you have chosen well, you are working on something you love. Isn't a day at the lab worth documenting with comparable level of detail? (hopefully with tools allowing far more time persistence than Snapchat…)

Scientists and engineers are just people, no matter what they say…



You don't have supernatural memory capabilities, and you're subject to mood swings and memory bias like everyone else. But the result of your research will be subject to really high standards of accuracy and reproducibility.

The notebook is your loyal companion

- While working in the lab, one goes through a number of different emotions. In any case, documenting is one of the best ways to deal with with these emotional states. For example:

- Excitement: Things are going great! Progress is extremely fast, adrenaline is high - it feels you could go on forever. Better document what you're doing, excitement and fast progress may quickly lead to forgotten details and irreproducible results.

- Boredom: It is time to run 250 different iterations of your experiment, or simulation, or whatever. Unmanaged tediousness will make your mind wonder, you will lose focus and possibly become sloppy. Better document what you'll be doing, what's the plan and clear steps, check things as they get done.

The notebook is your loyal companion

- Puzzlement: You can't make any sense of things. Results are strange or unexpected – is there anything wrong with the setup, or my code? In trying to understand, you'll rapidly change quite a few things – perhaps some of them at the same time. Better document what are you doing – you will quickly forget what you changed and when. Who knows – perhaps the thing that looks strange is the most interest result you have ever had!

- Sadness: Your experiment failed, despite your best efforts. You feel like shutting everything down and going away for two weeks to clear up your mind. Perhaps this is indeed the best thing you could do. Better document right away: there are usually valuable lessons that can be derived from failure, and you'll forget everything by the time you're back.

The notebook is your loyal companion

- You don’t know exactly what’s coming. Some of your work will be well defined and perhaps routinary, but some of your best results will not be planned. So it is good to keep comprehensive notes.

- We’ll be talking about paper notebooks and pens. There are also options in electronic media, and most of our comments will apply to either one. But just remember: we can still read Newton’s notebooks written in the 1600s, while I can’t read the floppies I used 10 years ago.

Purpose of lab notebook

- The purpose of a lab notebook is to keep a record of your activities (experiments, simulations, theoretical derivations, etc.) so you or someone else could repeat your work or understand exactly how it was done. The notebook is evidence of your work.

- Here are some purposes for a lab notebook:
  - Describing experiments and activities: reasons for experiments, how were they performed, what were the results.
  - Compiling data/charts/photos/ideas
  - It is a place where to find clues to troubleshoot problems
  - It is also a place to think and observe the whole picture
  - It serves as a legal document, to prove discoveries and patents
  - It can be used as defense against accusations of fraud or lawsuits

What do you write in a notebook

- Various disciplines may have slightly different conventions on how to write lab notebooks, and what to include.

- Here are some typical examples:
  - Complete description of experiments (reasons, setup, etc.)
  - Complete record of procedures, data, and thoughts to pass to others researchers (including your future self!)
  - Computer generated data, photos, printouts, all other data
  - Hand-made graphs (make as you go to quickly see trends and perhaps make decisions)
  - Datasheets, product labels, names of providers/vendors
  - Notes (or pasted copies) of discussions, conversations, emails, readings related to your goals and/or activities
  - Locations of equipment, sensors, etc.
  - Items that can't be fitted in the notebook may be kept on a separate folder or storage location. Always cross-reference these materials and corresponding pages in the notebooks.

A simple template for daily annotations

1. Date

2. Objective of the day. Short paragraph describing what is objective of the day, problem to be solved. The technique to be used. It can simply refer to the previous day, annotating any change

3. Clear diagram of the set up with sufficient detail to be reproduced. Again it can refer to a previous diagram, and only annotate any modification.

4. Data. All data is recorded, included "bad shots" with conditions at which they are taken and comments.. Reference to digital data location

5. Graphs/plots of results must be included

6. Main conclusions, including what might have gone wrong!

DOs and DON'Ts for keeping lab notebooks

1. Do use bound books (good, acid-free paper)
2. Do sign and date
3. Do use ink (no pencil, please)
4. Don't leave blank spaces
5. Don't modify (do not modify written records, and do not erase – strike through instead. NEVER remove pages)
6. Do use past tense
7. Do explain abbreviations and special terms
8. Do staple attachments (do not leave loose pieces of paper in your notebook)
9. Don't remove originals (make your own copies, if allowed)
10. Do outline new experiments
11. Do record lab meeting discussions
12. Do provide detail
13. Do track notebooks
14. Do save completed notebooks

http://techtransfer.tufts.edu/resources/tufts-policies/lab-notebooks/

Some helpful tips

- Always record as you go
- Write legibly
- Don’t hesitate in cutting and gluing material to your notebook – it is better than trying to transcribe the information. Use acid-free glue or high quality tape.
- A table of contents is very useful. You can leave room for it when you start a new notebook, and fill it up as you go.

More useful tips

- When you work for others, you do not own “your” notebook. Your employer does.

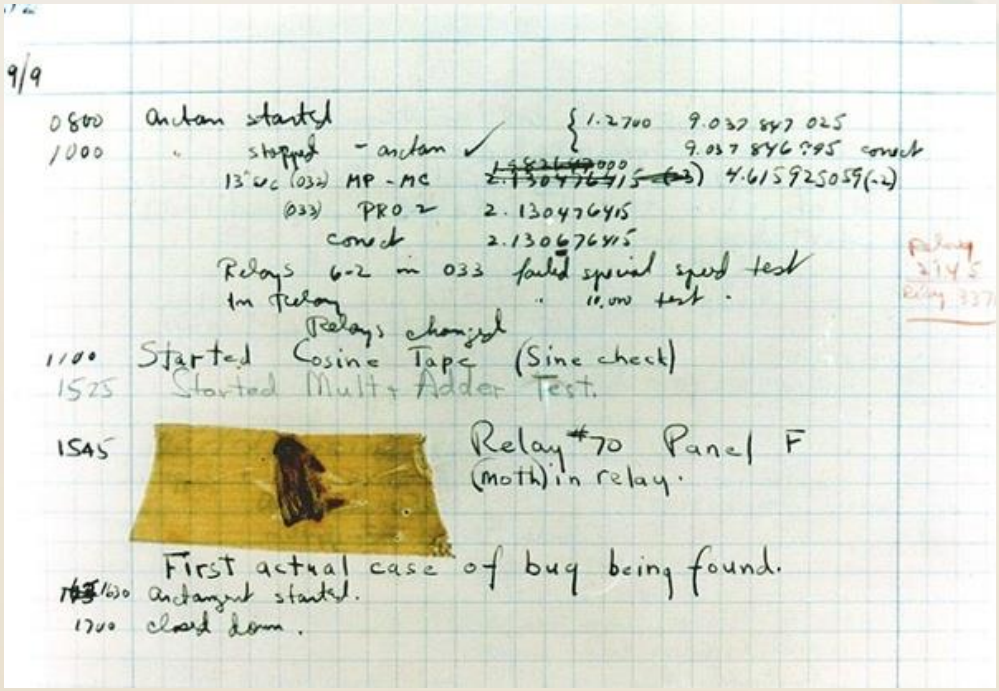
- Do not remove notebooks from the lab, unless there is express permission to do so.

- You may ask for a copy. Depending on the specifics of your employer’s intellectual property agreement (usually signed by you on the first day of employment) you may be allowed a copy. Also, make sure you’re aware of the record retention policies of your employer.

SOME EXAMPLES OF RESEARCH NOTEBOOKS

First instance of actual computer bug being found

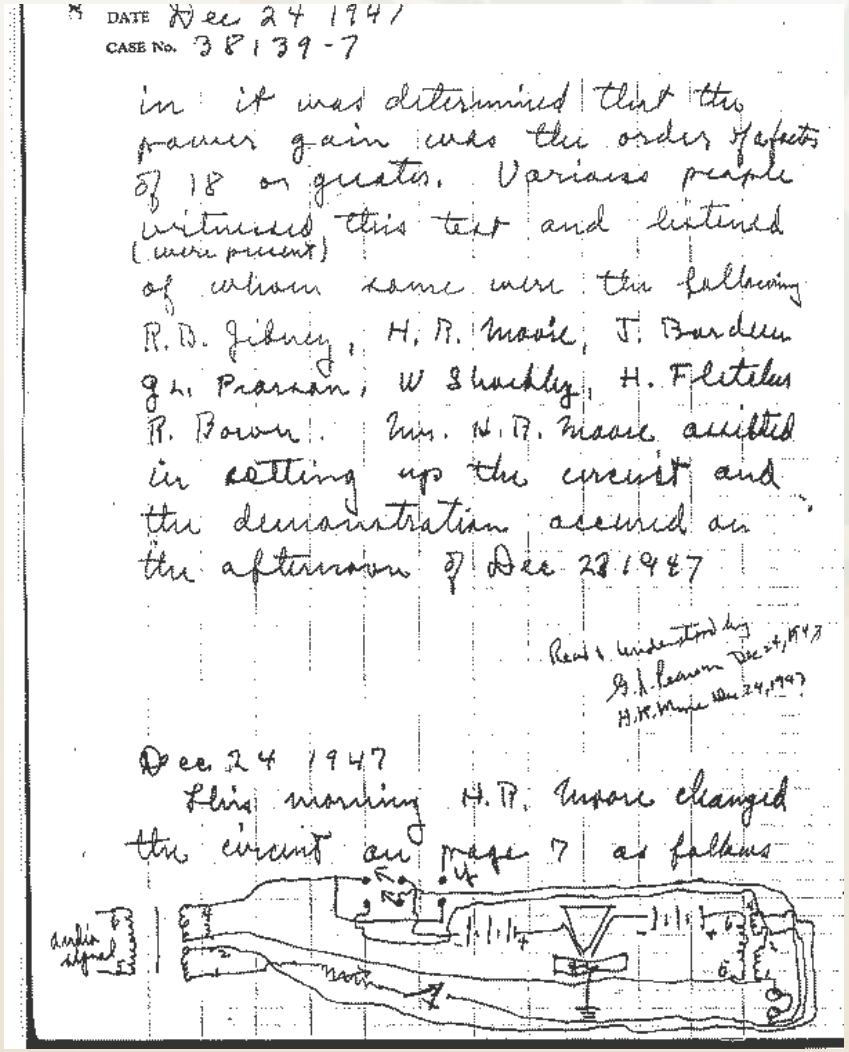
September 9, 1945. At 3:45 p.m., Grace Murray Hopper records the first computer bug in her log book as she worked on the Harvard Mark II. The problem was traced to a moth stuck between a relay in the machine, which Hopper duly taped into the Mark II's log book with the explanation: “First actual case of bug being found.”



http://www.computerhistory.org/tdih/September/9/

First transistor

Walter Brattain, December 24, 1947: This page records the moment when the first transistor was shown to the higher-ups at Bell Labs. A microphone and headphones were connected to the transistor, and the device was actually spoken over "with no noticeable change in quality" writes Brattain. On the page is listed the people who were there to witness the occasion, including Gibney, Moore, Bardeen Pearson, Shockley and others.


DATE Dec 24 1947
CASE No. 38139-7

in it was determined that the power gain was the order of factors of 18 or greater. Various people witnessed this test and listened (were present) of whom some were the following R. D. Gibney, H. R. Moore, J. Bardeen G. L. Pearson, W Shockley, H. Fletcher R. Bown. Wm. H. R. Moore assisted in setting up the circuit and the demonstration occured on the afternoon of Dec 24 1947

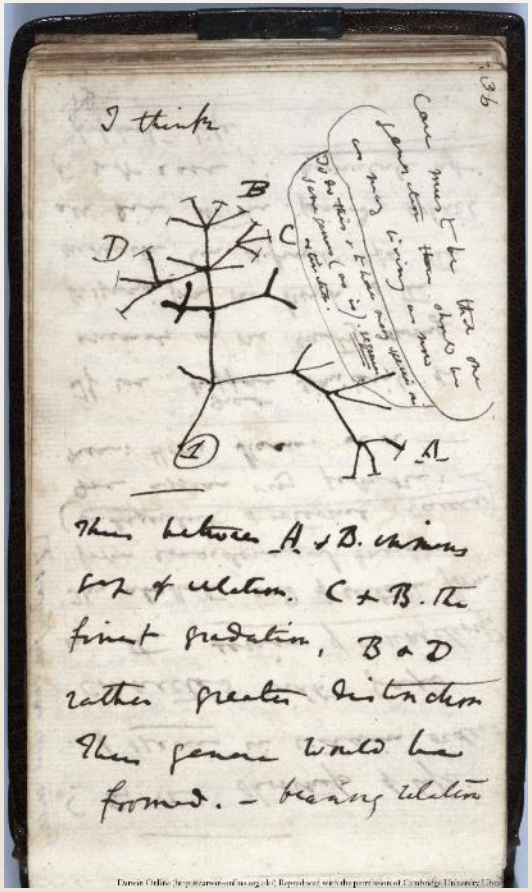
Read & understood by G. L. Pearson Dec 24, 1947 H. R. Moore Dec 24, 1947

Dec 24 1947
This morning H. R. Moore changed the circuit on page 7 as follows

audio signal

http://www.pbs.org/transistor/science/labpages/labpg6.html

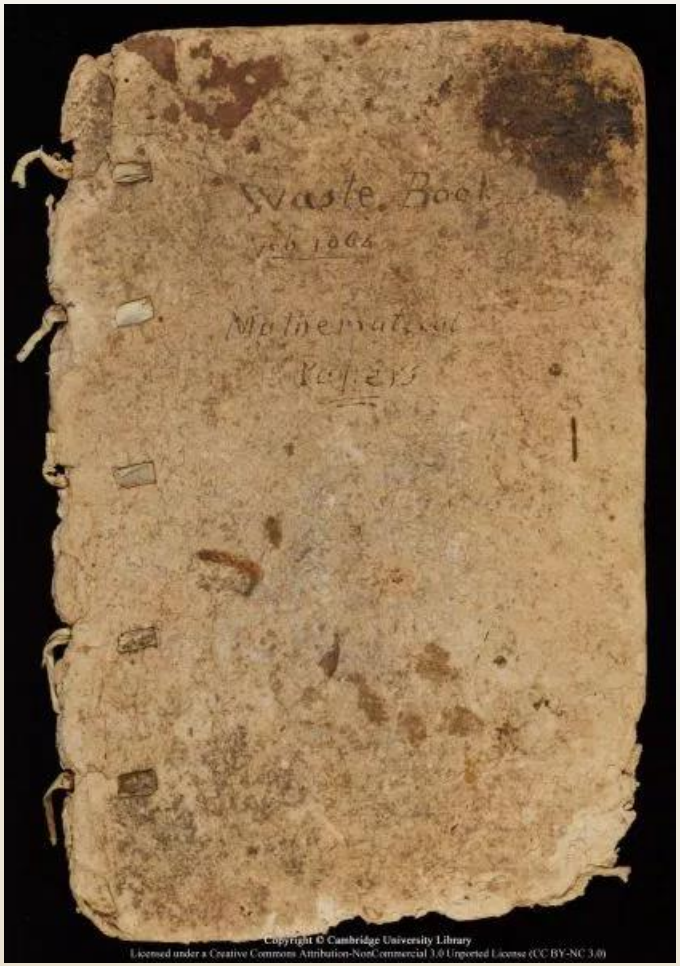
Darwin's notebooks



Darwin kept his notebooks by his side throughout his voyage on the HMS Beagle. During his journey, he filled dozens of notebooks with his scientific discoveries as well as general musings and mundane lists. When making zoological and botanical observations, he would write every detail of a species' variations as well as sketch drawings of the subject for reference. Much of what Darwin kept in his notebooks ended up in his revolutionary On the Origin of Species. Here is one of Darwin's sketches of an evolutionary tree, the very first of its kind.

http://darwin-online.org.uk/EditorialIntroductions/vanWyhe_notebooks.html
http://pencils.com/famous-notebook-users/

Newton’s notebooks

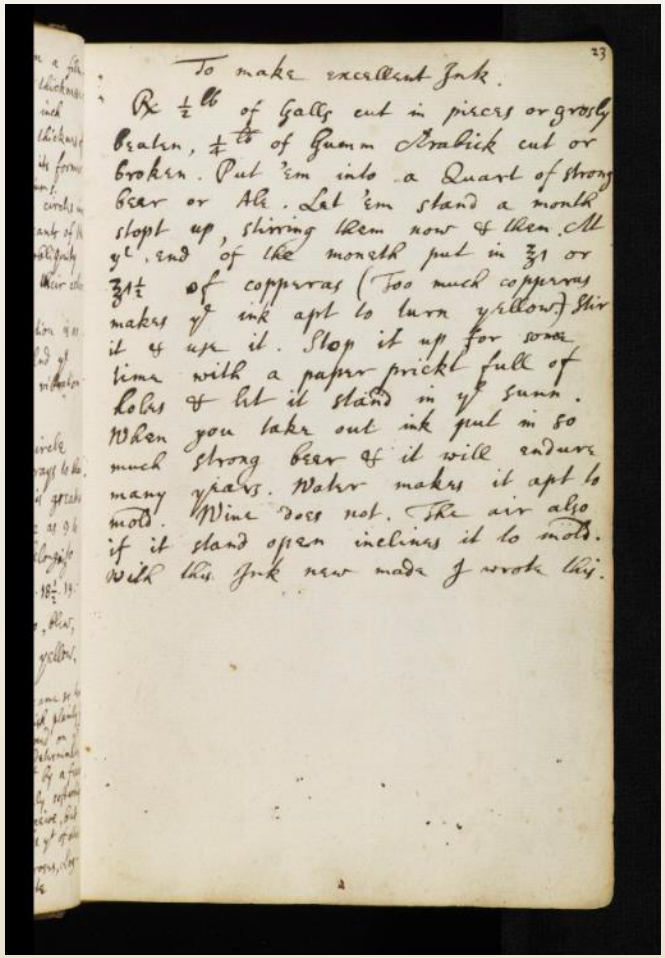


Newton’s Waste Book:

Much of Newton's important work on calculus is developed in this large notebook, which he began using in 1664 when he was away from Cambridge due to the plague.

http://cudl.lib.cam.ac.uk/view/MS-ADD-04004/1

Newton’s notebooks



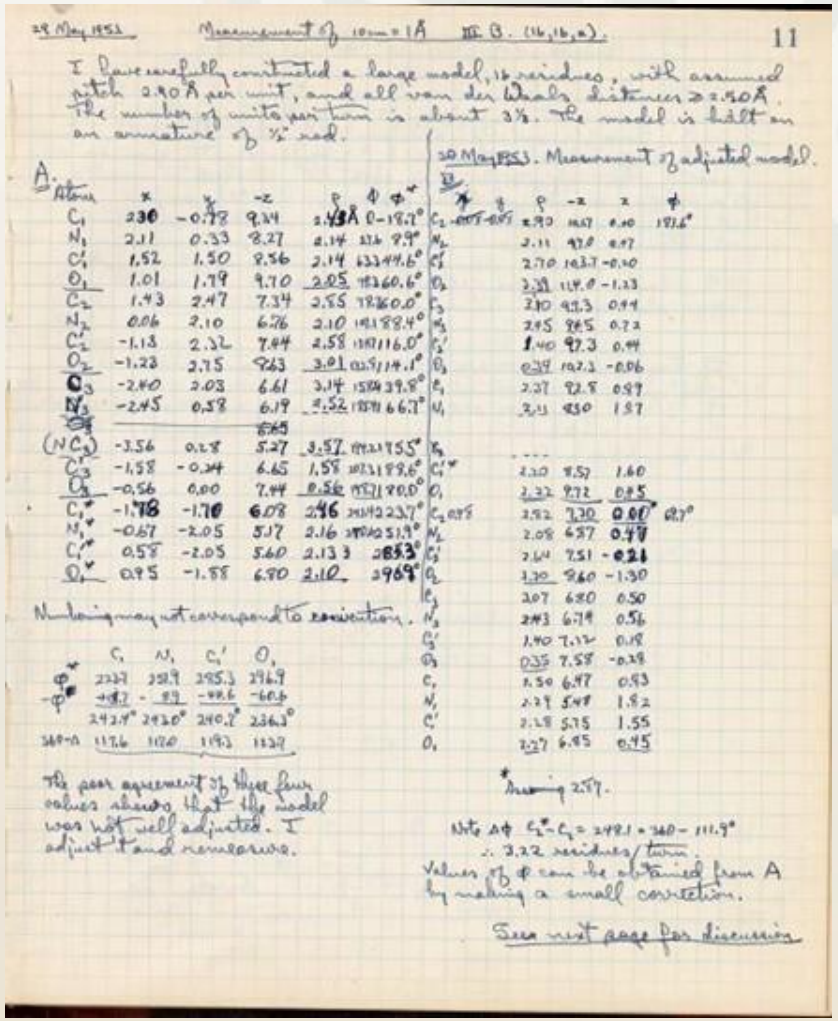
Laboratory Notebook (MS Add.3975)

Newton's notes on optics, precious stones, colors, temperatures, salts, medical matters, alchemy and other subjects, in English and Latin, c. 1669-c.1693.

http://cudl.lib.cam.ac.uk/view/MS-ADD-03975/29

Linus Pauling: Protein α-helix

- May 29, 1951. In this page from Linus Pauling' s lab notebook, he describes his discovery of the protein alpha-helix. He won his first Nobel prize in 1954 for the work described here, the first real insight into the 3D structure of proteins.



29 May 1951 Measurement of 10cm = 1Å Ill B. (16,16,a). 11

I have carefully constructed a large model, 16 residues, with assumed pitch 2.90 Å per unit, and all van der Waals distances ≥ 2.90 Å. The number of units per turn is about 3⅓. The model is built on an armature of ½" rod.

A.

Atom	x	y	-z	ρ	Φ	Φ*
C_1	2.30	-0.78	9.34	2.43 Å	0-18.2°	
N_1	2.11	0.33	8.27	2.14	224 9.9°	
C_1'	1.52	1.50	8.56	2.14	323 44.6°	
O_1	1.01	1.79	9.70	2.05	18 260.6°	
C_2	1.43	2.47	7.34	2.55	78 260.0°	
N_2	0.06	2.10	6.76	2.10	141 88.4°	
C_2'	-1.13	2.32	7.44	2.58	137 116.0°	
O_2	-1.23	2.75	9.63	3.01	135 114.1°	
C_3	-2.40	2.03	6.61	3.14	158 39.8°	
N_3	-2.45	0.58	6.19	2.52	188 66.7°	
			8.65			
(NC_3)	-3.56	0.28	5.27	3.57	192 21.5°	
C_3'	-1.58	-0.34	6.65	1.58	302 89.6°	
O_3	-0.56	0.00	7.44	0.56	180 90.0°	
C_1^*	-1.78	-1.70	6.08	2.46	224 23.7°	
N_1^*	-0.67	-2.05	5.17	2.16	270 51.9°	
$C_1'^*$	0.58	-2.05	5.60	2.13 3	285.3°	
O_1^*	0.95	-1.88	6.80	2.10	296.9°	

Numbering may not correspond to convention.

	C_1	N_1	C_1'	O_1
Φ^*	232.7	252.9	295.3	296.9
$-\Phi^*$	-48.7	-89	-99.6	-60.4
	242.9°	293.0°	240.2°	236.3°
360-Δ	117.6	117.0	119.3	113.7

The poor agreement of these four values shows that the model was not well adjusted. I adjust it and remeasure.

30 May 1951. Measurement of adjusted model.

	ρ	-z	x	Φ
C_2	2.90	10.57	0.40	187.6°
N_2	2.11	9.70	0.97	
C_2'	2.70	10.37	-0.40	
O_2	2.38	11.9	-1.23	
C_3	2.30	9.53	0.99	
N_3	2.95	9.85	0.72	
C_3'	1.40	9.73	0.99	
O_3	0.39	10.23	-0.06	
C_1	2.27	9.28	0.97	
N_1	2.43	8.30	1.57	
C_1'	2.20	8.57	1.60	
O_1	2.32	9.72	0.85	
C_1^*	2.52	7.30	0.00*	0.7°
N_1^*	2.08	6.57	0.78	
$C_1'^*$	2.64	7.51	-0.21	
O_1^*	1.30	9.60	-1.30	
C_2	2.07	6.80	0.50	
N_2	2.43	6.79	0.56	
C_2'	1.40	7.12	0.18	
O_2	0.35	7.58	-0.28	
C_3	1.50	6.97	0.93	
N_3	2.29	5.49	1.82	
C_3'	2.28	5.15	1.55	
O_3	2.27	6.95	0.95	

* Assuming 2.57.

Note $\Delta\Phi$ $C_2^*-C_1$ = 248.1 - 360 - 111.9°
∴ 3.22 residues/turn.
Values of Φ can be obtained from A by making a small correction.

See next page for discussion

http://scarc.library.oregonstate.edu/coll/pauling/rnb/index.html

Fairchild Semiconductor: Genesis of Silicon Valley

Some notebooks from Fairchild

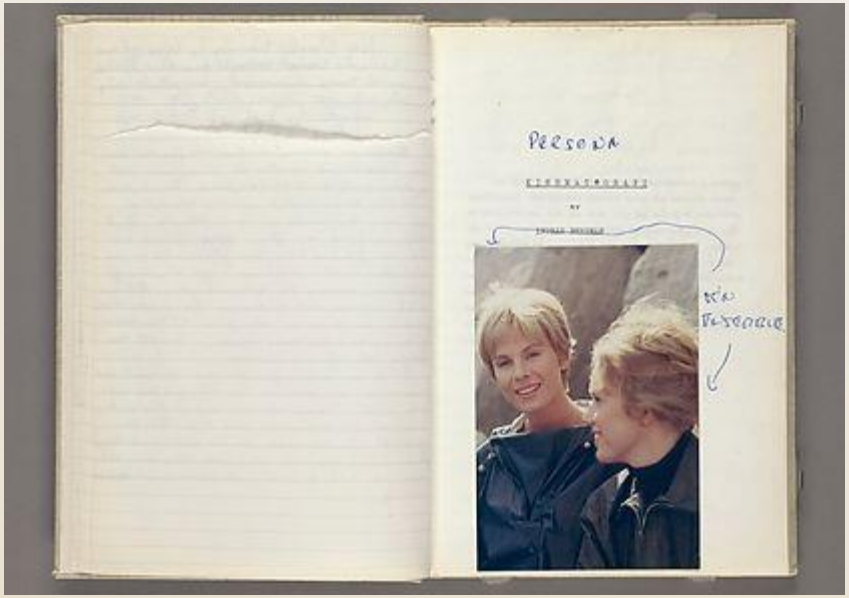
Transistor chip photos from Gordon Moore's notebook

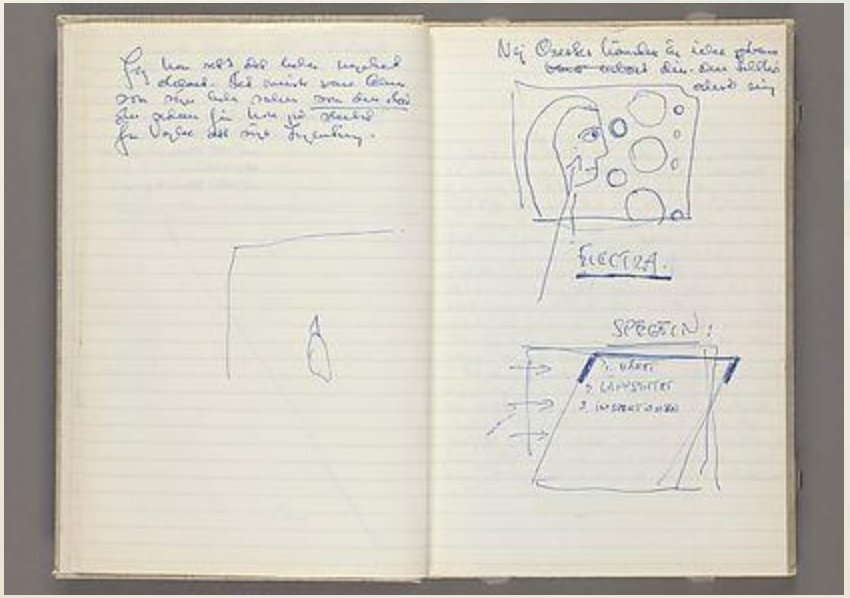
First page of Robert Noyce's IC patent disclosure

http://www.computerhistory.org/atchm/the-fairchild-semiconductor-collection-of-notebooks-and-technical-papers/

Ingmar Bergman: Persona

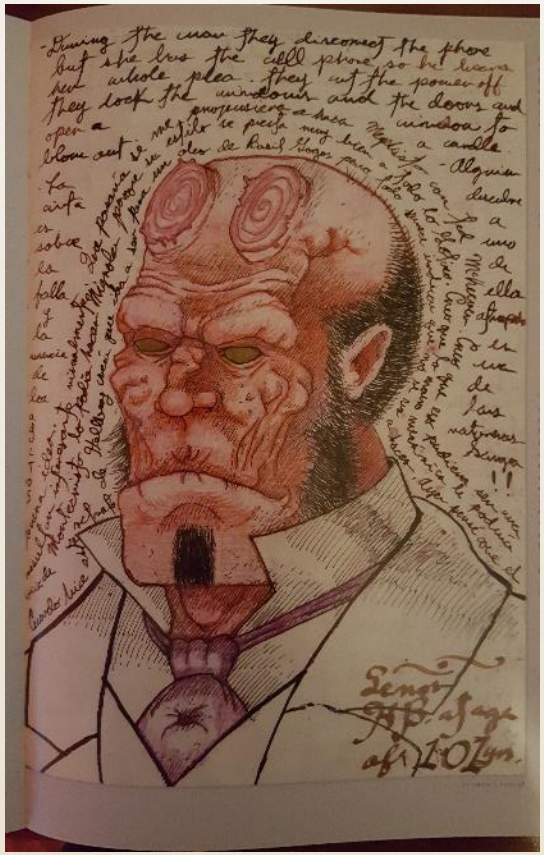
Persona is a 1966 B&W Swedish film written and directed by Ingmar Bergman and starring Bibi Andersson and Liv Ullmann. The film is shot and set in Sweden and deals with the themes of illness, bleakness, death and insanity. It is considered one of the major works of the 20th century.

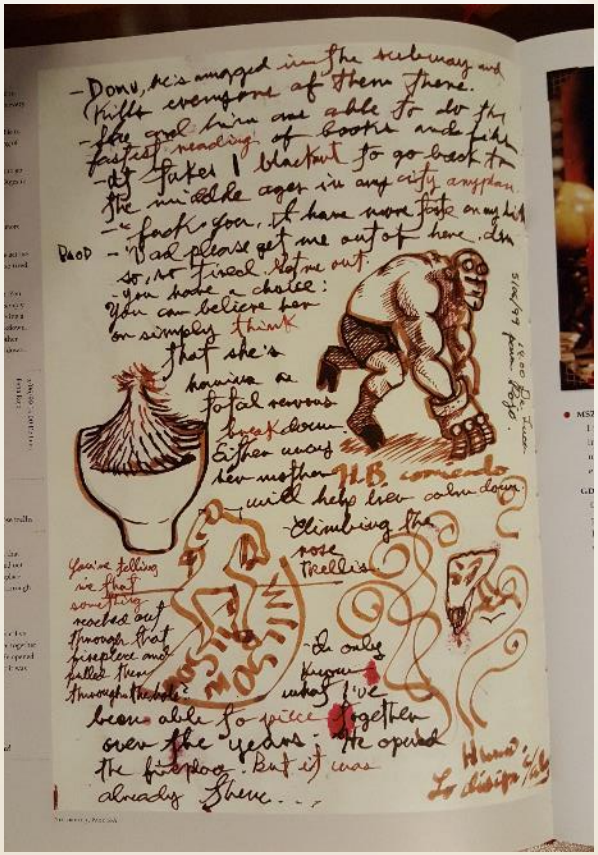




http://ingmarbergman.se/en/archive/blog/archival-object-day-11

Guillermo del Toro: Hellboy





Notebooks as Idea Incubators

"Before I start shooting a movie, I read all the notebooks. They travel with me. I consider the notebooks a catalog… like a mail-order catalog of ideas…
I like to say that we make only one movie in our lifetime – a movie made of all the images of all our movies… I think these books are important to me because they narrate the story of that single movie I'm trying to make."

Guillermo del Toro, "Cabinet of Curiosities" (Harper Design, NY 2013)

SOME EXAMPLES CLOSER TO HOME

REVIEW OF SCIENTIFIC INSTRUMENTS **79**, 013503 (2008)

Spectroscopically pure metal vapor source for highly charged ion spectroscopy and capillary discharge soft x-ray lasers

F. G. Tomasel
NSF Center for Extreme Ultraviolet Science and Technology and Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado 80523, USA and Advanced Energy Industries, Fort Collins, Colorado 80525, USA

V. N. Shlyaptsev
Department of Applied Science, University of California Davis Livermore, Livermore, California 94551, USA

J. J. Rocca
NSF Center for Extreme Ultraviolet Science and Technology and Department of Electrical and Computer Engineering, Colorado State University, Fort Collins, Colorado 80523, USA and Department of Physics, Colorado State University, Fort Collins, Colorado 80523, USA

(Received 18 August 2007; accepted 26 November 2007; published online 17 January 2008)

We describe a compact, pulsed metal vapor source used for the production of dense plasma columns of interest for both soft x-ray laser research and spectroscopy of highly ionized plasmas. The source generates spectroscopically pure cadmium vapor jets in a room-temperature environment by rapidly heating an electrode with a capacitive discharge. In the configuration described herein, the metal vapor jet produced by the source is axially injected into a fast (up to 15 kA/ns), high current (up to 200 kA peak) capillary discharge to generate highly ionized cadmium plasma columns. Spectroscopic analysis of the discharge emission in the 12–25 nm spectral range evidences the dominance of Cu-like (CdXX) and Ni-like (CdXXI) lines and shows strong line emission at 13.2 nm from the $4d\ ^1S_0$–$4p\ ^1P_1$ laser transition of Ni-like Cd. Hydrodynamic/atomic physics simulations performed to describe the dynamics of the plasma column and compute the optimum discharge conditions for laser amplification are discussed. © *2008 American Institute of Physics.*
[DOI: 10.1063/1.2825459]

A paper published about eight years after the experiments were performed. Writing the paper was made possible, in part, by meticulous record keeping.

8/30 – FINAL APPROXIMATION USING Γ

Γ IS COMPLICATED BECAUSE OF ABS FUNCTION. LET'S SEE $\Gamma^2 = \Gamma\Gamma^*$

$$\frac{\partial \Gamma^2}{\partial X_{SH}} = -\frac{(Z_0^* - Z_P^* + jX_S)\,\sigma_3}{\sigma_1\sigma_4} - \frac{(Z_P - Z_0 + jX_S)\,\sigma_2}{\sigma_1\sigma_4} + \frac{(Z_0^* + Z_P^* - jX_S)\,\sigma_2\sigma_3}{\sigma_1^2\sigma_4} + \frac{(Z_0 + Z_P + jX_S)\,\sigma_2\sigma_3}{\sigma_1\sigma_4^2}$$

$$\sigma_1 = X_S Z_0^* - jX_S X_{SH} + X_{SH} Z_0^* + X_{SH} Z_P^* + j Z_0^* Z_P^*$$

$$\sigma_2 = jX_S X_{SH} + X_S Z_0^* + X_{SH} Z_0^* - X_{SH} Z_P^* + jZ_0^* Z_P^*$$

$$\sigma_3 = jX_S X_{SH} - X_S Z_0 - X_{SH} Z_0 + X_{SH} Z_P + jZ_0 Z_P$$

$$\sigma_4 = jX_S X_{SH} + X_S Z_0 + X_{SH} Z_0 + X_{SH} Z_P - jZ_0 Z_P$$

$$\frac{\partial \Gamma^2}{\partial X_S} = -\frac{(Z_0 + jX_{SH})\,\sigma_2}{\sigma_1\sigma_4} - \frac{(Z_0^* + jX_{SH})\,\sigma_3}{\sigma_1\sigma_4} - \frac{(-Z_0^* + jX_{SH})\,\sigma_2\sigma_3}{\sigma_1^2\sigma_4} + \frac{(Z_0 + jX_{SH})\,\sigma_2\sigma_3}{\sigma_1\sigma_4^2}$$

$$\sigma_1 = Z_0^*(X_S + X_{SH}) - jX_S X_{SH} + Z_P^*(X_{SH} + jZ_0^*)$$

$$\sigma_2 = Z_0^*(X_S + X_{SH}) + jX_S X_{SH} + Z_P^*(-X_{SH} + jZ_0^*)$$

$$\sigma_3 = -Z_0(X_S + X_{SH}) + jX_S X_{SH} + Z_P(X_{SH} + jZ_0)$$

$$\sigma_4 = Z_0(X_S + X_{SH}) + jX_S X_{SH} + Z_P(X_{SH} - jZ_0)$$

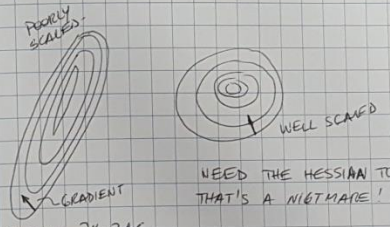
$$\Delta\Gamma^2 = \frac{\partial \Gamma^2}{\partial X_{SH}}\Delta X_{SH} + \frac{\partial \Gamma^2}{\partial X_S}\Delta X_S$$

$\vec{v} = -\nabla\Gamma^2$ we want to move along $\vec{v}$

QUITE EXPRESSIONS, BUT NOT GUARANTEED TO BE REAL.

8/31 I HAD AN ERROR ON THE MATLAB CODE – IT EXECUTES OK NOW (IT WAS PRODUCING COMPLEX ΔC BEFORE)

DRIVING BY GRADIENT SOUNDS LIKE A GOOD IDEA, EXCEPT WHEN THE PROBLEM IS POORLY SCALED



NEED THE HESSIAN TO IMPROVE. BUT THAT'S A NIGHTMARE!

IT WILL ZIG-ZAG

APPROXIMATION TO THE HESSIAN ARE AVAILABLE, BUT IMPLEMENTATION IS NOT TRIVIAL. AMONG OTHER THINGS, PREVIOUS VALUES NEED TO BE STORED AND STEP SIZE NEEDS TO BE ESTIMATED, USING FOR EXAMPLE LINE SEARCH

BFGS IS AN EXAMPLE, WHERE AN APPROXIMATION TO THE HESSIAN IS GIVEN BY

$$B_{k+1}^{-1} = B_k^{-1} + \frac{(s_k^T y_k + y_k^T B_k^{-1} y_k)(s_k s_k^T)}{(s_k^T y_k)^2} - \frac{B_k^{-1} y_k s_k^T + s_k y_k^T B_k^{-1}}{s_k^T y_k}$$

$$s_k = \alpha_k p_k, \quad y_k = \nabla f(x_{k+1}) - \nabla f(x_k)$$

p_k IS THE SEARCH DIRECTION

SO I THINK I'LL STICK TO ADMITTANCE (OR IMPEDANCE) DRIVING FOR FINAL APPROXIMATION, IF EVER NEEDED.

50

750 W, 40 sccm $p = 1.2 \times 10^{-4}$ Torr

$I_1 =$ 4.1 A
$I_2 =$ 38-39 A
$V_1 =$ 175-185 V
$V_2 =$ ~~0.0~~ 1.04-1.08 kV

$f =$ 2.129 - 2.132

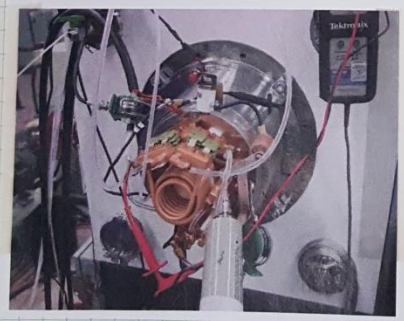
750 W, 25 sccm 7.8×10^{-5} Torr

$I_1 =$ 4.1-4.7 A
$I_2 =$ 43-47 A
$V_1 =$ 195-207 V
$V_2 =$ 1.19-1.24 kV

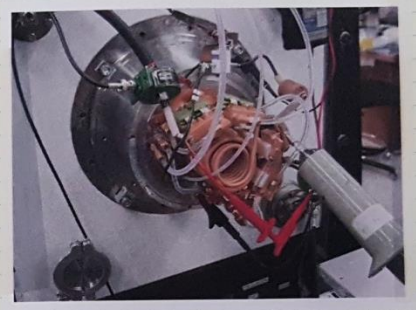
$f =$ 2.13

At lower pressure it extinguishes.

* Correction to observation on page 49 - Ignition was not working properly because the sweeping range was too narrow. Now set to 2.07 – 2.146 MHz.

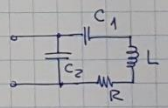


51



Capacitive match:

For a "series" configuration:



$$Z_{RLC} = R + i(X_L + X_{C_1})$$

$$Y_{RLC} = \frac{1}{R + i(X_L + X_{C_1})} = \frac{R - i(X_L + X_{C_1})}{R^2 + (X_L + X_{C_1})^2} \qquad Y_{C_2} = -\frac{i}{X_{C_2}}$$

$$Y_T = \underbrace{-\frac{i}{X_{C_2}} - \frac{i(X_L + X_{C_1})}{R^2 + (X_L + X_{C_1})^2}}_{=0} + \underbrace{\frac{R}{R^2 + (X_L + X_{C_1})^2}}_{=1/R_6} = \frac{1}{R_6}$$

$$\Rightarrow \quad R_6 = \frac{R^2 + (X_L + X_{C_1})^2}{R} \quad \Rightarrow \quad X_{C_1} = \sqrt{R(R_6 - R)} - X_L$$

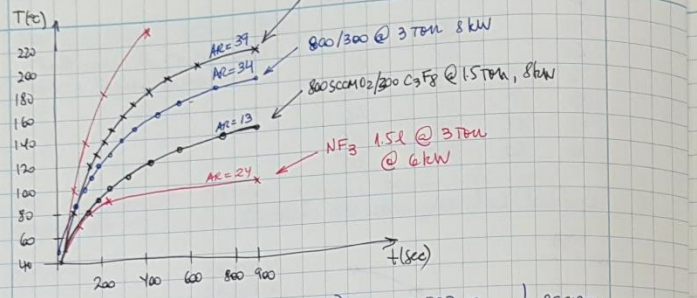
$$X_{C_2} = -\frac{R^2 + (X_L + X_{C_1})^2}{X_L + X_{C_1}} = -\frac{R_6 R}{X_L + X_{C_1}}$$

$$C_1 = \frac{1}{\omega\left[X_L - \sqrt{R(R_6 - R)}\right]} \qquad C_2 = \frac{X_L + X_{C_1}}{\omega R_6 R}$$

10

AR = AVERAGE ETCH RATE

[AR] = Å/min



RECIPE # 2 — 1000 Ar / 1000 O2 / 300 C3F8 @ 3 TOR, 8 kW

INITIAL WEIGHT 179.735 gr
FINAL WEIGHT 179.153 gr
Δ = 0.582 gr

Run: 15 min Rate 39 mg/min

* RECIPE #3 800 SCCM O2 / 300 SCCM C3F8 @ 8 kW, 1.5 TOR

INITIAL WEIGHT 179.137 gr
FINAL WEIGHT 178.945 g
Δ = 0.192 13 mg/min

* RECIPE 1.6 slm O2 / 600 SCCM C3F8 @ 8kW, 1.5 TOR
High Voltage Warning - Unit turns off

* RECIPE 1.2 slm O2 / 450 SCCM C3F8
Unit turns off

COMPOSITION (O2/C3F8)	VOLTAGE	CURRENT
800/100	77	56
800/200	95	52
800/300	116	56
1000/200	91	52
1000/300	146	56
1000/400	198	74
1000/500	179	85
1600/300	115	56
1600/400	148	75

P = 1.5 TOR

11

ALL 15-min RUNS

* RECIPE #4 800/300 @ 8kW, 3 TOR — VOLTAGE 199, CURRENT 75

INITIAL WEIGHT: 178.863 gr
FINAL WEIGHT: 178.355 gr
Δ = 0.508 gr 34 mg/min

#3		#2		#4		#5		#6		#7		#8		
T	t	T	t	T	t	T	t	T	t	T	t	T	t	
40	24	40	15	50	3	50	36	60	16	50	20	50	23	
50	51	50	28	60	24	60	55	70	40	60	31	60	32	
60	83	60	42	70	45	70	77	80	65	70	41	70	41	19
70	116	70	56	80	68	80	99	90	92	80	51	80	50	32
80	152	80	72	90	94	90	125	100	121	90	61	90	60	43
90	195	90	88	100	124	100	155	110	154	100	74	100		54
100	248	100	107	110	157	110	183	120	191	110	87	110		65
110	316	110	129	120	194	120	228	130	235	120	101	120		78
120	410	120	152	130	237	130	273	140	284	130	115	130		91
130	536	130	175	140	290	140	325	150	344	140	131	140		—
140	750	140	210	150	355	150	395	160	420	150	148	150		117
145	900	150	250	160	434	160	483	170	515	160	166	160		137
		160	300	170	540	170	609	180	653	170	187	170		159
		170	347	180	712			190	900	180	210	180		182
		180	410	1865	900					190	235	190		240
		190	502							200	285	200		285
		200	630							210	300	210		324
		210	900							220	340	220		373
										230	410			

* RECIPE #5 1000 O2 / 300 C3F8 @ 8kW 3 TOR — V = 150, I = 75A

INITIAL WEIGHT: 178.355 gr
FINAL WEIGHT: 178.052 gr
Δ = 0.303 gr AR = 25

STOPPED @ 12 min

* RECIPE #6 800/300 C3F8 @ 3 TOR 8 kW — Same as Recipe # 4

INITIAL WEIGHT 178.052 gr
FINAL WEIGHT 177.573 gr
Δ = 0.479

160 V, 75 A

AR = 0.032 gr/min

14

MARCH 3 2002

STATUS:

→ WE ORDERED THE CALIBRATION LAMPS FOR THE SPECTROMETER ON FEB 26 PR# 1106 2510

Hg (Ar) lamp, Ne lamp, power supply & FO accessories.

→ CALLED ACTON NEAS TODAY TO GET TRANSMITTANCE DATA FOR THE FIBER OPTIC BUNDLE.

MARCH 1 → WE DISCUSSED POSSIBLE EXPERIMENTS ON DC MAGNETRONS - FAST PHOTOGRAPHY FOR ARC OBSERVATION

[redacted]

From: [redacted]
Sent: [redacted]
To: [redacted]
Subject: Fast gated imaging

[redacted]

I've taken a look to our camera. The total insertion delay of the camera plus the cable connecting the camera to the controller plus the delay of the controller itself is 62 ns. To that we have to add the delay of the trigger cable from the DC power supply (~1.5 ns/foot) and the time response of the DC power itself to detect the onset of the spark and send the trigger signal out. For an arc duration of 1 usec or more, seems to me that we are OK. We will need an adapter to mount the focusing optics. I just talked to Roper and they have an adaptor that will work with any conventional Nikon lens. The price of the adaptor is U$210. To that we should add the price of an standard Nikon lens, which may be around U$150.
With an f/1.2 or f/1.8 lens we won't have problems with the focal depth.

[redacted]

CALLED ROPER SCIENTIFIC. JAMES MONKOWSKI @ [redacted]

ADAPTER ORDERED ON 3/3/02 - PART # 7389-0002

THE CAMERA IS NOW DISMOUNTED FROM THE SPECTROMETER.

MARCH 19, 2002

15

NIST Atomic Spectra Database Data

Page 1 of 3

ASD DATA — LINES LEVELS — INFORMATION — LIST OF SPECTRA, GROUND STATES & IONIZATION ENERGIES, BIBLIOGRAPHY, HELP

NIST Atomic Spectra Database Lines Data (Wavelength Ordered)
Wavelength=5000 Å, ± 2500 Cu I
45 Lines of Data Found
(For this lines search, there is no energy level information in the database.)

Wavelength Air (Å)	Rel. Int.	A_{ki} (10^8 s^{-1})	$g_i g_k$	Line Refs.
2 618.37	2500*r*	3.07e-01	6-4	290
2 766.37	2500*r*	9.6e-02	4-4	290
2 824.37	1250*r*	7.8e-02	6-6	290
2 961.16	2500*r*	3.76e-02	6-8	290
2 997.36	2000			290
3 010.84	2000			290
3 036.10	2500			290
3 063.41	2500	1.55e-02	4-4	290
3 073.80	1400			290
3 093.99	1500			290
3 099.93	1250			290
3 108.60	2000			290
3 126.11	1400*w*			290
3 194.10	1500	1.55e-02	4-4	290
3 208.23	1400			290
3 243.16	1500*w*			290
3 247.54	10000*r*	1.39e+00	2-4	290
3 273.96	10000*r*	1.37e+00		290

http://physics.nist.gov/cgi-bin/AtData/display.ksh

3/18/2002

JUNE 25/03

Dividing m.a.m.

$$\frac{\cos\left[2\arccos(1/4) - 5\pi/6\right]}{\cos\left[\arccos(1/4) - \pi/6\right]} = \frac{\cos\left[(3\pi/2) - \varphi\right]}{\sqrt{3}\cdot\cos\left[(\pi/3) + \varphi - \arccos(1/4)\right]}$$

$$\Rightarrow \sqrt{3}\cdot 1.43 = \frac{\cos(3\pi/2 - \varphi)}{\cos(2\pi/3 - \varphi)} \Rightarrow 2.48 = \frac{\cos(270° - \varphi)}{\cos(120° - \varphi)}$$

$$2.47 = \frac{\cos(3\pi/2 - \varphi)}{\cos\left[\pi/3 + \varphi - \arccos(1/4)\right]}$$

$$2.47 = \frac{\cos(270° - \varphi)}{\cos(\varphi - 15.52°)} \Rightarrow \boxed{\varphi = 125°}$$

$$U_R^* = U_N \cdot \frac{\cos\left[2\arccos(1/4) - 5\pi/6\right]}{\cos\left[3\pi/2 - \varphi\right]}$$

$$U_R^* = U_N \cdot (1,22)$$

$$\frac{U_R^*}{\sin\left(2\arccos(1/4) - 5\pi/6\right)} = \frac{U_N}{\sin(3\pi/2 - \varphi)}$$

$$\frac{U_R^*}{\sin\left(\arccos(1/4) - \pi/6\right)} = \frac{U_N}{\sqrt{3}\sin\left(\pi/3 + \varphi - \arccos(1/4)\right)}$$

By dividing m.a.m. and rearranging

$$\frac{\sin\left(\arccos(1/4) - \pi/6\right)}{\sqrt{3}\sin\left(2\arccos(1/4) - 5\pi/6\right)} = \frac{\sin\left(\pi/3 + \varphi - \arccos(1/4)\right)}{\sin(3\pi/2 - \varphi)}$$

$$22.587 = \frac{\sin(\varphi - 15,5225°)}{\sin(270° - \varphi)} \rightarrow \boxed{\varphi \doteq 92.5°}$$

$$U_R^* = \frac{\sin\left(2\arccos(1/4) - 150°\right)}{\sin(270° - \varphi)} U_N \Rightarrow \boxed{U_R^* \doteq 0.42\, U_N}$$

CAPACITORS : 4 pcs in parallel

220μF x 450V DC _ CDE CORNELL-DUBILIER
TYPE 381LR221M450J452
25mmØ x 45mm HEIGHT _ 105°C
1,42A @ 120Hz / 105°C

* Advantages of using L/C

L = 1.5mHy @ 12,5A RMS
C = 880μF

- Lower line current harmonics
- No EMI filter (possibly)
- Lower RMS current on hold up capacitor
- Minimum voltage on bus during 50% sag is 218v
- Protection from line overvoltage.

ALTERNATIVE CAPACITOR : NICHICON 220μF x 400v
Ø25mm x 45mm _ Imax = 1.24A @ 120Hz
TYPE : LAQ2G 221MHLA45

JUNE/27

→ NO SPACE ENOUGH INSIDE EMI ENCLOSURE.

Using the L selected.

* Calculating a different alternative:

C = 210μF x 450VDC _ (x3) → 630μF ← CORNELL-DUBILIER
105°C _ 2A RMS @ 120Hz _ 384mΩ/120Hz TYPE 450C
L = 1mHy @ 13A. LONG LIFE
450C211M450AK8
Ø35 x 45mm page 2.147 CDE

JUNE/30

- MOVE BOTTOM SIDE COMPONENTS ON RF PCB TO THE TOP
- CHECK USING ANOTHER DIODE IN SERIES FOR CLAMPING CKT.
- CHECK COLDPLATE TYPE ETC AND NEED FOR 4TH RF SECTION.
- QUALIFY CT FOR RF
- QUALIFY PSHM 40/06
- CAPACITORS : 450C211M450AK8
- READ ALBRIGHT POC
- PARTS → GATHER

54

LINE INDUCTOR

MICROMETALS INDUCTORS FOR P
POWERLINE FREQUE

ELECTRICAL PROPERTIES DATA

INDUCTANCE AT MAX CURRENT:	1000.00	micro HENRIES	MI
MAXIMUM DC RESISTANCE	0.00	OHMS (Optional)	FR
MAXIMUM CURRENT	13	AMPERES RMS	TE
INDUCTANCE AT MIN CURRENT:	800.00	micro HENRIES	

CORE P/N (# Stacked)	PRICE US$	AL nH	TURNS	WIRE AWG	%FILL	Rdc
T157-70 x3	3.73	390	51	# 12	36.9	0.0355

MICROMETALS INDUCTORS FOR
POWERLINE FREQ

DIMENSIONAL PROPERTIES DATA

INDUCTANCE AT MAX CURRENT:	1000.00	micro HENRIES	I
MAXIMUM DC RESISTANCE	0.00	OHMS (Optional)	F
MAXIMUM CURRENT	13	AMPERES RMS	T
INDUCTANCE AT MIN CURRENT:	800.00	micro HENRIES	

CORE P/N (# Stacked)	CORE DIMENSIONS. in OD	ID	HEIGHT	MAGNETIC, cm Ac	Lm
T157-70 x3	1.570	0.950	1.710	3.18	10.10

CONNECTOR P1 : 3501476

- TALK TO STEVE DILLON : SIZE OF DSP BOARD _ CONNECTOR POSITION _ . DXF
- ASK JJ ABOUT FILTER EMI .

JULY 9TH

TASKS LIST

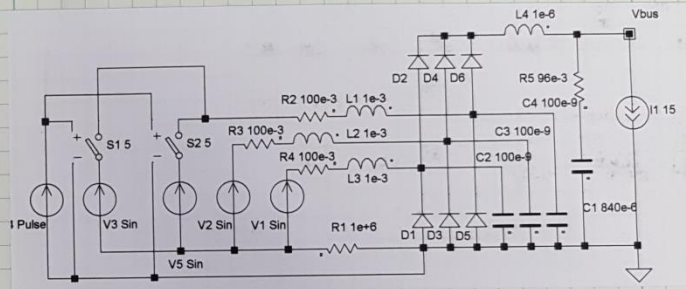
1. _ Set up to work old power supply to test capacitors (RF section)
2. _ Design and define EMI Filter
3. _ Re design and fit (mechanical) CT for RF section
4. _ Check DSP pcb. Ready to be produced by July 17TH
5. _ Ask Dillon . DXF file for DSP pcb.
6. _ Safe copy all files somewhere.
7. _ Check production of Control (Digital) pcb. U$S 350 ea ~ Quotes
8. _ Check RF pcb. Ready by July 10TH → Send to assembly
9. _ Check status of cold plate.
10. _ Parts sent to be qualified.
11. _ Power board DC/DC : a) _ Schematics (find components) → Fuse box, Connectors, Module, Caps.
    b) _ Layout → core with pin #1 conn. → CT
12. _ Ask Dillon . DXF file for Power board.
13. _ Control program for DC/DC Converter.
14. _ Parts gathering → check.
15. _ X parts ___ See what's going on.

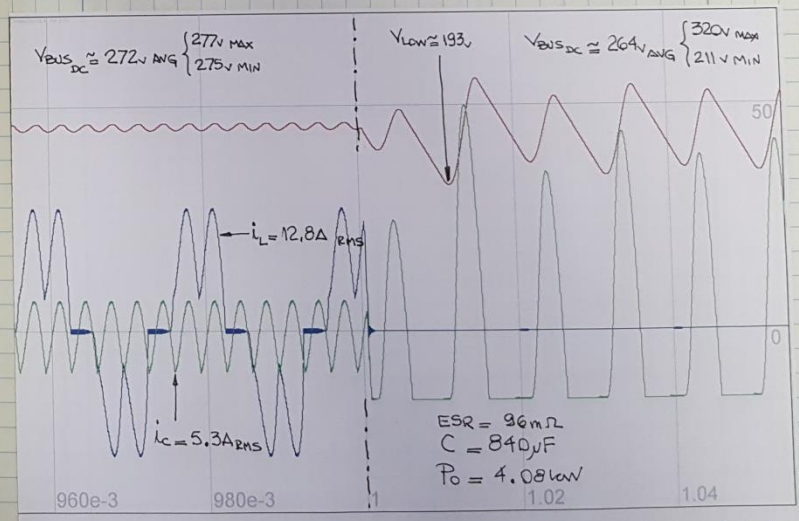
55

JULY 10TH

- We're not going to use other capacitors than CDE because of board space!
- Check height of connector P2 on power board, below DSP board.
- Who's going to send .sch to Warren for approval?
- What to do waiting for parts to be qualified.
- Fuse blocks on PCB (power).
- Qualify Aux. Supply

F-47 COMPLIANCE (4 CDE 210 µF x 450 V HOLD UP)





Summary

- Maintaining good notebooks is essential for all sorts of activities, ranging from scientific research to the arts.
- Writing notebooks is part of a much broader endeavor: the creation, documentation and dissemination of knowledge. Discovery without communication is not worth much to others.
- If nothing else, you should do it for your own sake: among many other benefits it will help you to continuously improve your work and your communication skills, it will minimize time wasted, and it will show that you are a professional - someone who cares enough to write down and analyze what he/she does.

A simple template for daily annotations

1. Date
2. Objective of the day. Short paragraph describing what is objective of the day, problem to be solved. The technique to be used. It can simply refer to the previous day, annotating any change
3. Clear diagram of the set up with sufficient detail to be reproduced. Again it can refer to a previous diagram, and only annotate any modification.
4. Data. All data is recorded, included "bad shots" with conditions at which they are taken and comments.. Reference to digital data location
5. Graphs/plots of results must be included
6. Main conclusions, including what might have gone wrong!